Exploration Systems
Health Management Facilities and Testbed Workshop

Testbed Capabilities at the John F. Kennedy Space Center

Presentation Agenda

- Technology Maturation Pipeline (The Plan)
- Cryogenic testbed (and other KSC Labs)
  - Component / Subsystem technologies
- Advanced Technology Development Center (ATDC)
  - System / Vehicle technologies
- ELV Flight Experiments (Flight Testbeds)

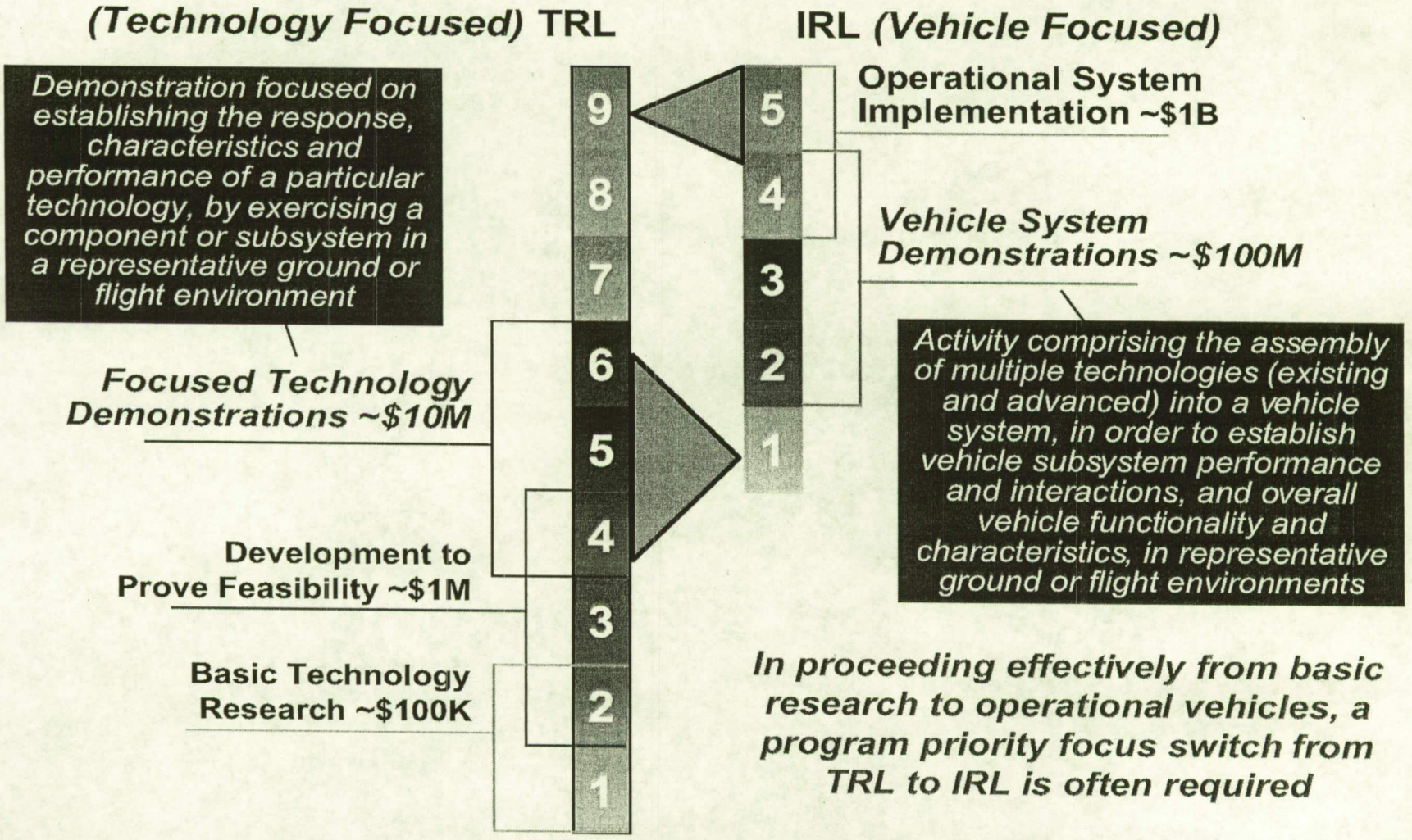
Technology Maturation Pipeline
(Overview)

- Technology Maturation Issue: How does one gain confidence that inter-system interactions will lead to operationally effective solutions?

- Solution: Network of generic technology integration capabilities that create full compatible architectural elements mature enough for production

- Technology laboratories have logical destinations for risk reduction across all the technical disciplines—programs don't have to bear unaffordable systems integration/risk reduction burdens

Technology Maturation Pipeline
(TRL/IRL Relationship)



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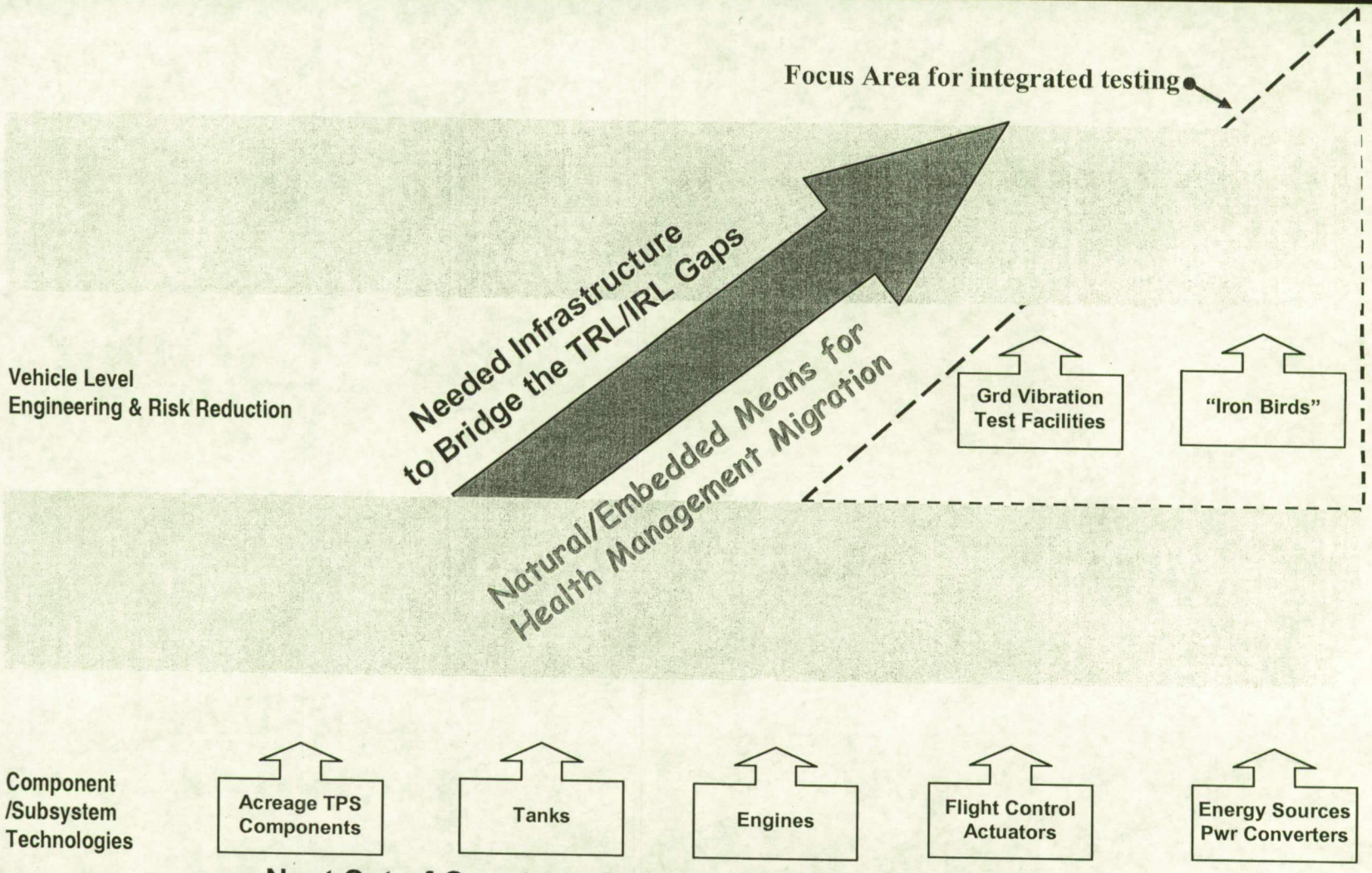
Technology Maturation Pipeline

(Technology Pipeline Infrastructure)



Next Set of Concepts & Technologies in Roadmap

Technology Maturation Pipeline

(Technology and Integration Readiness Demonstrations – Why is it necessary?)

Provides an opportunity to:

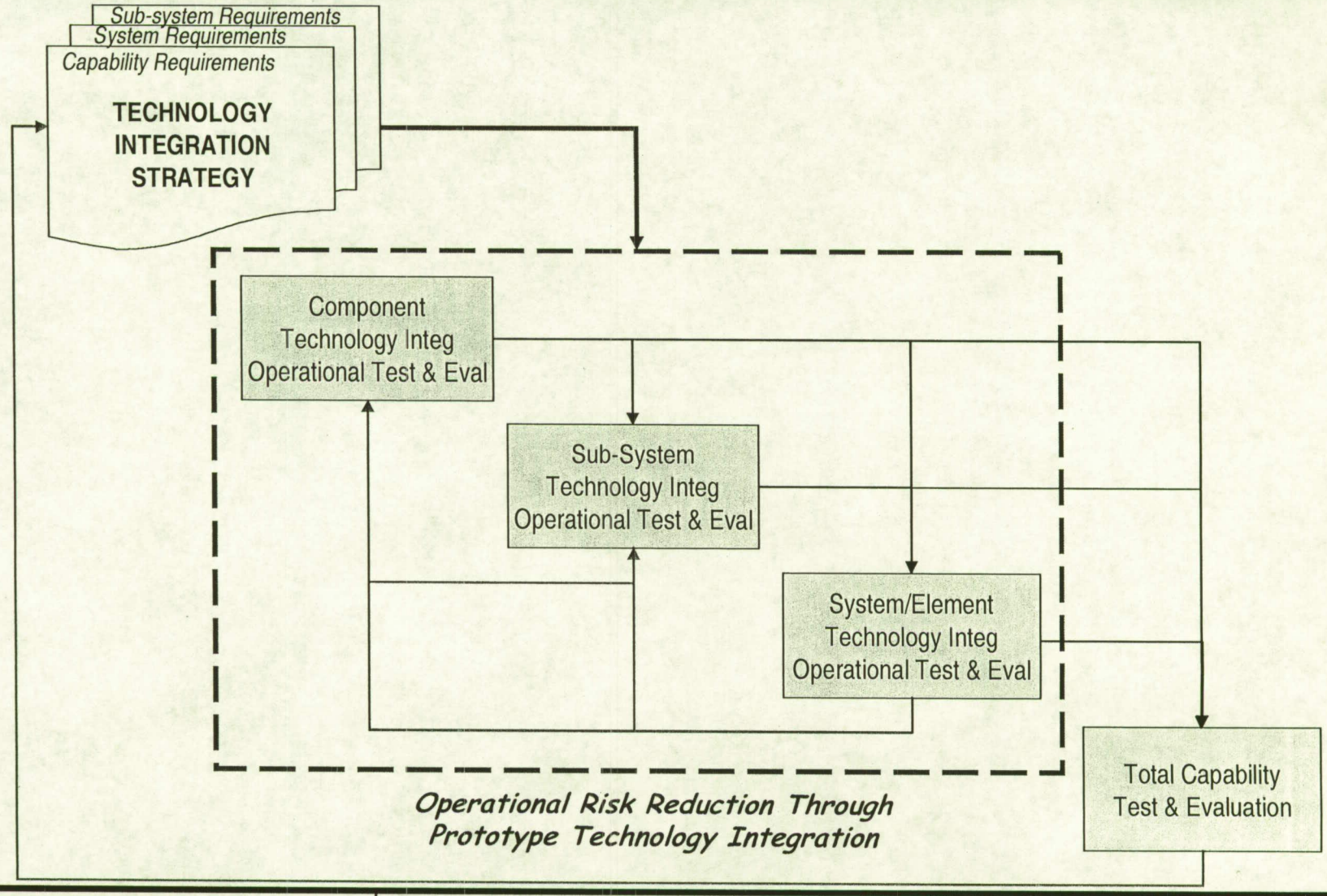
- Validate high technology and integration readiness levels
- Demonstrate compliance with performance requirements
- Identify performance constraints
- Discover unknown technical issues related to system interfaces and integration
- Reduce risk of technology development and integration
- Perform assessments in regard to operability, maintainability, and reliability and provide feedback to technology developers and vehicle designers
- Validate operational modeling and simulation assessments
- Assess health management needs based on life cycle failure data
- Conduct training for the civil service and contractor workforce

These demonstrations may be performed without risking damage to flight hardware and impacts to normal operations.

Technology Maturation Pipeline

(Pipeline for Technology Maturation with Corrective Action Mechanisms)

HEALTH MANAGEMENT TESTBED WORKSHOP

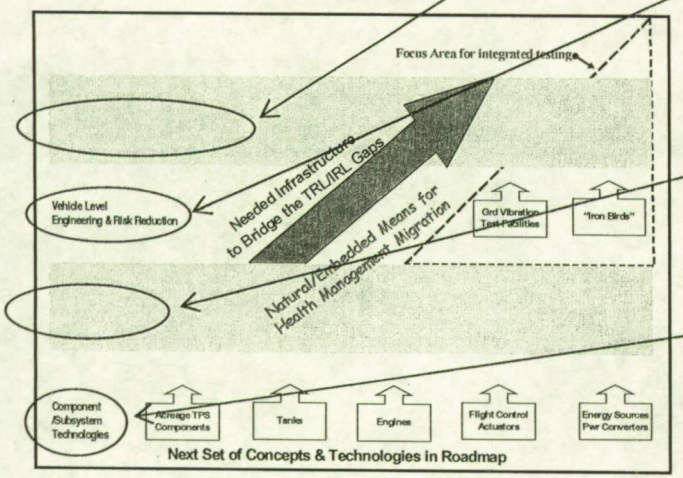


Technology Maturation Pipeline
(Approach)

- Conduct an assessment of technologies being developed by potential customers and review their concept of operations
- Assist customers in identifying testing and integration needs for ground demonstrations and flight testing that addresses all of the identified issues and concerns
- Identify candidate technologies ready to enter into maturation pipeline
- Develop integrated product/customer teams to determine the best ways test and integrate all advanced concepts and technologies.
- Identify and quantify the benefits of technology testing and integration from component to the subsystem, element, and vehicle, if applicable (must have some benefit to NASA).
  - Intent is to bring technologist, operators, and maintainers together on a single joint service team with a shared purpose to identify, mature, demonstrate, and transition technologies and concepts that meets NASA's needs while reducing the life cycle cost and increasing operational readiness.
- Jointly develop a plan for risk reduction activities with control gates and exit strategies
- Good open and frequent communication at all times

Testbeds

(Where they fit with the Technology Maturation Pipeline Approach)



Testbeds for: Architectural Prototype - Demonstration of Operational Effectiveness
- Expendable Launch vehicles (ELV) Flight Testbeds

Testbeds for: Vehicle Level - Engineering & Risk Reduction
- Advanced Technology Demonstration Center

Testbeds for: System Level - Engineering & Risk Reduction
- Cryogenics Testbed
- Launch Systems Testbed

Testbeds for: Component / Subsystem Technologies
- Electrostatics and Surface Physics Testbed
- Corrosion Technology Testbed
- Failure Analysis Laboratory
- Space Life Sciences Laboratory
- Biological & Chemical Test and Analysis Laboratory

Technology Maturation Pipeline
(Final Thoughts)

- A high priority should be given to building and testing prototypes and subsystems before proceeding with full-scale development.

- Demonstrations should be used to validate performance predictions and for providing a realistic basis for making cost estimates prior to full-scale development

- Work together with NASA Centers, DoD, industry, and academia to mature technologies and mitigate technical risks that result in improved vehicle performance, operational efficiency, and overall safety.

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Testbeds for Component/Subsystem Technologies

(Surface Cryogenics and Consumables)

- **Rationale**
  - The requirements for a Moon/Mars based cryogenic depot involves the same features as its earth-based analog; Storage, Distribution, and Liquefaction.
  - Role: Technology and System Development (JSC - System Integrator)
  - **KSC expertise**:
    - Cryogenic thermal insulation
    - Liquefaction
    - Storage and distribution
    - Thermal Modeling
    - Leak Detection
    - Umbilicals
    - Control Systems
    - Cryo Ops
  - **Capabilities**
    - Cryo Testbed
    - Advanced Technology Demonstration Complex
    - Transducer Testbed
    - LETF
    - Subsystem scale environmental chamber
  - **Exploration Related Technology Development**
    - Pumping LOX with Magnetic Fields
    - Deployable Cryo Tank
    - Super-insulation Research
    - Autonomous Umbilicals
    - Thermal switch research

Testbeds for Component/Subsystem Technologies

(Cryogenics Testbed – Projects and Experience)

- **Application Projects**
  - Development and evaluation of long distance transfer piping, ETB
  - Development and evaluation of materials and test equipment for cryogenic systems, CDDF
  - Development and evaluation of composite insulation for heat transfer study of flexible piping, CDDF
  - Evacuated Microsphere Insulation Panels: SBIR, Phase II, Technology Applications, Inc.
  - Cryogenic Transfer Line with Magnetic Suspension: SBIR, Phase II, AMAC International, Inc.
  - Cryogenic Tank Insulation, Testing of Candidate Materials for 2nd Generation Launch Vehicles (SLI): NASA/LaRC, Boeing, Northrop Grumman, NASA/MSFC
  - Thermal characterization cryostat testing glass bubbles, Technology Applications, Inc.
  - Insulation testing including compression, Lockheed-Martin
  - Cryogenic Propellant Insulation Program: SBIR, Phase I, Technology Applications, Inc.
  - Novel Lightweight, Low-Cost, Aerogel Materials as Insulation for Cryogenic Tanks: SBIR, Phase I, Aspen Aerogels, Inc.

- **Collaboration Projects**
  - Flexible Piping for HT Superconducting Power Cables, DOE/Oak Ridge National Lab
  - Thermophysical properties measurement of cryogens, Florida State University / National High Magnetic Field Laboratory
  - Cryogenic thermal insulation systems analysis, University of Central Florida / Florida Solar Energy Center
  - Performance of Perforated MLI Blanket, Fermi National Accelerator Laboratory
  - Aerogel and Aerogel Composites Development, Cabot Corporation, Aspen Aerogels Inc., NASA/ARC, NASA/MSFC
  - Cryo-Medical Applications, University of Central Florida
  - Air Cargo Refrigerated Transport, University Laval, Quebec
  - Collapsible Cryogenic Storage Vessel, Florida Tech

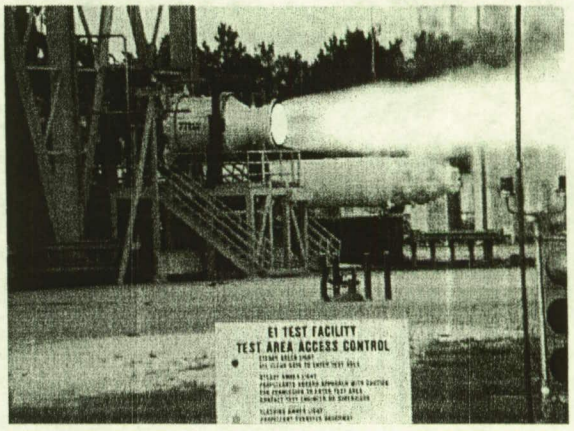
- **Research Projects**
  - Heat Transfer Study for Flexible Lines
  - Thermal Performance of MLI in Actual Field Installations
  - Performance Characterization of MLI Blankets
  - Advanced Insulation Systems for CO2 Environments and Mars
  - Development of New Layered Composite Insulation (LCI) for Manufacture
  - Structural Insulating Panels for Cryogenic Tanks and Containers

Testbeds for Component/Subsystem Technologies

(Launch Systems Testbed)

Provides the capability to perform scaled testing and development of launch systems subjected to the moving rocket exhaust plume environment.

Conducted the SLC-37 Acoustic Study for the Boeing EELV (Delta IV). The study provided Boeing with the vibration environment in seven zones on the launch tower, one zone in the launch mount, and within the concrete base of the pad. Vibroacoustic response methodologies were used to generate the environments in the tower and launch mount. Empirical scaling from Shuttle data was used to provide the vibration environment in the pad base. This was a cost reimbursable project accomplished under a Space Act Agreement.



Test involving SSC Partner

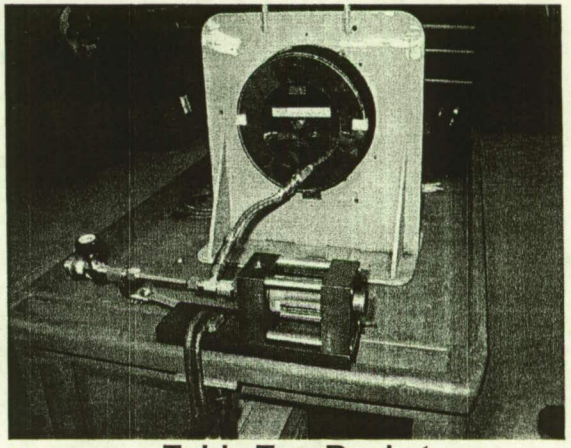


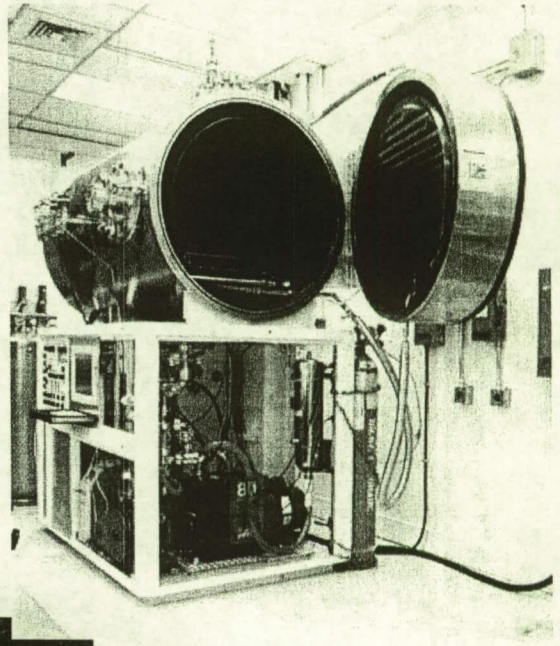
Table Top Rocket
(Flow Model Studies)

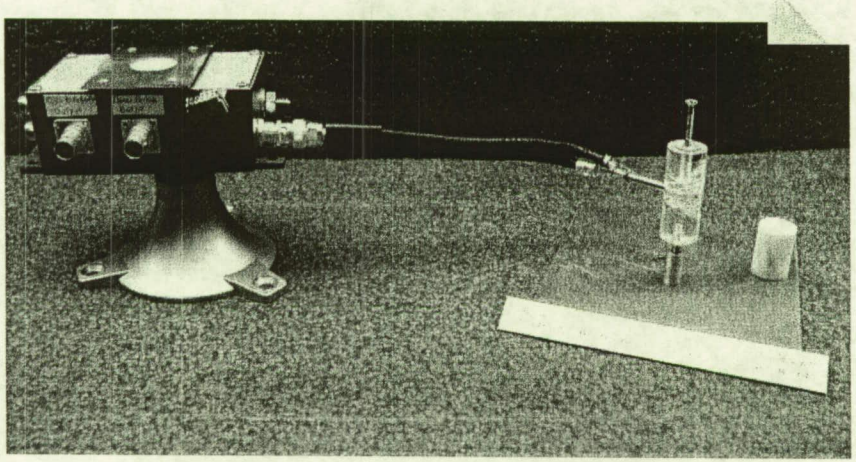
Testbeds for Component/Subsystem Technologies

(Electrostatics and Surface Physics Testbed)

Research and Development of Electrostatic Instrumentation for Planetary Missions and in electrostatic characterization of Mars and Lunar simulant soils and their interaction with different materials under simulated environmental conditions.

Designing an aerodynamic multisensor electrometer and a low pressure atmospheric dust particle impeller to measure the electrostatic and triboelectric properties of martian atmospheric dust and to identify the main mineral components of this dust. JPL has partnered with our Testbed on an NRA proposal based on this technology which was recently submitted from KSC.



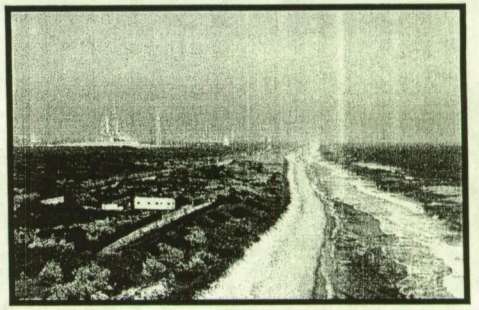


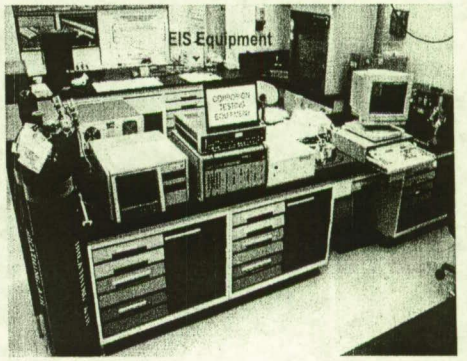
Testbeds for Component/Subsystem Technologies

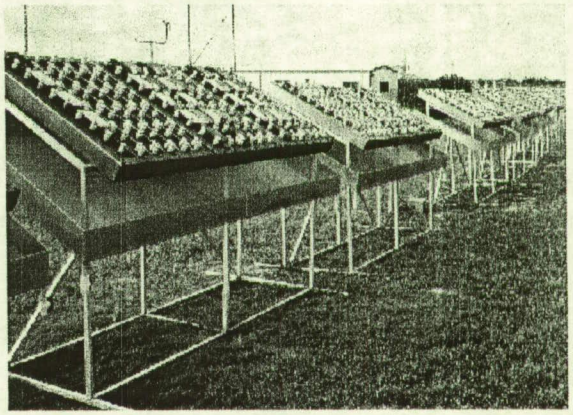
(Corrosion Technology Testbed)

Outfitted with state-of-the-art equipment to develop new corrosion control technologies and to investigate, evaluate, and determine material behavior in many different corrosive environments.

Army Aviation in Huntsville, Alabama, is paying KSC $ 900K to test and evaluate chloride rinse agents (CRAs) for use on Army aircraft, missile, and ground vehicle systems and components. Nine different metals are being subjected to the harsh, outdoor marine environment at the NASA/KSC Beach Site Corrosion Facility.







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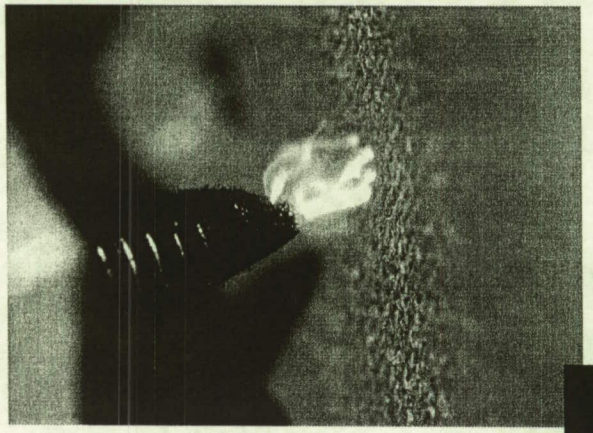
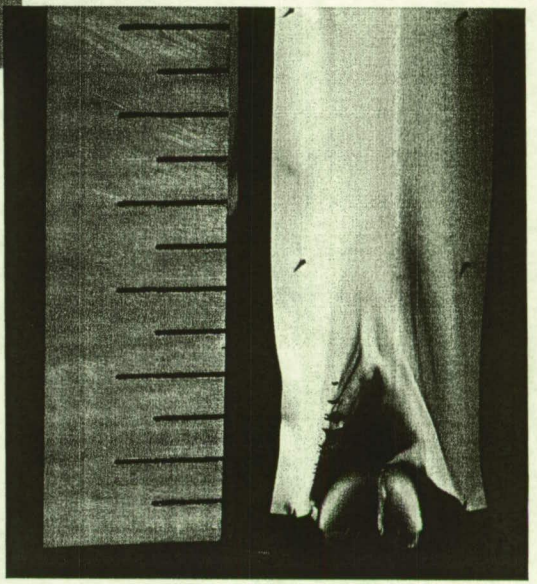
Testbeds for Component/Subsystem Technologies

(Mechanical Test & Materials Analysis Laboratory)

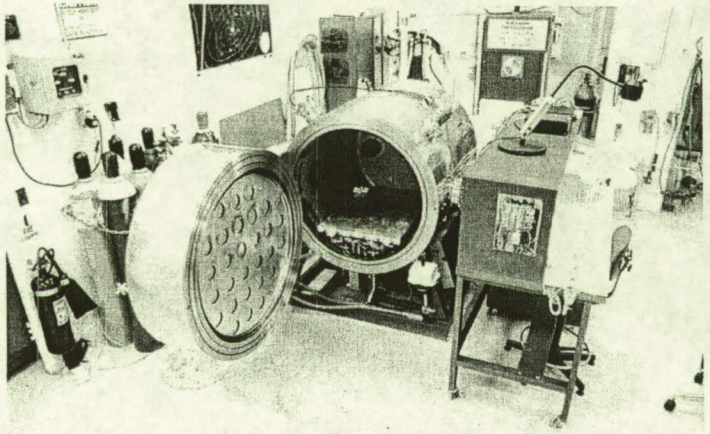
Mechanical / Materials Testing

- Tensile / compression
- Vibration & shock
- Flammability
- Materials compatibility
- Electrostatic discharge
- Thermal/vacuum





Collected oxygen & hypergol compatibility data for new Superaustenitic stainless steels that Testbeds personnel have recommended for use in tubing applications at LC-39



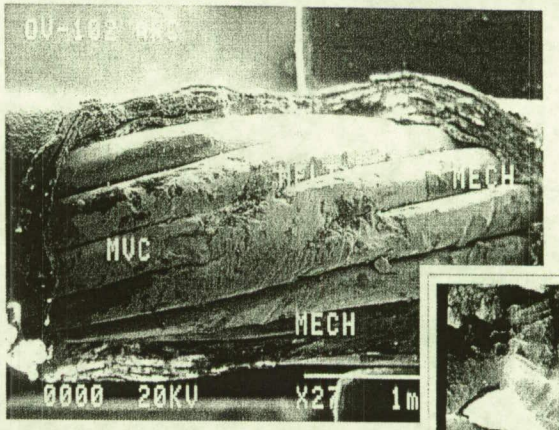
Testbeds for Component/Subsystem Technologies

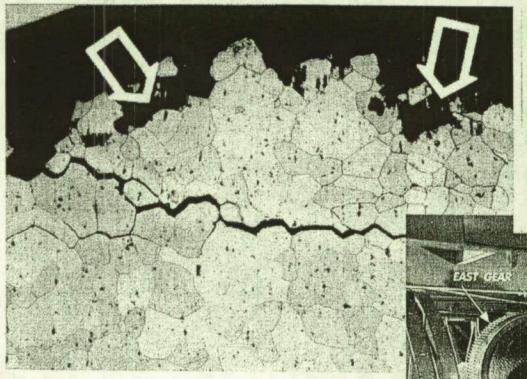
(Mechanical Test & Materials Analysis Laboratory)

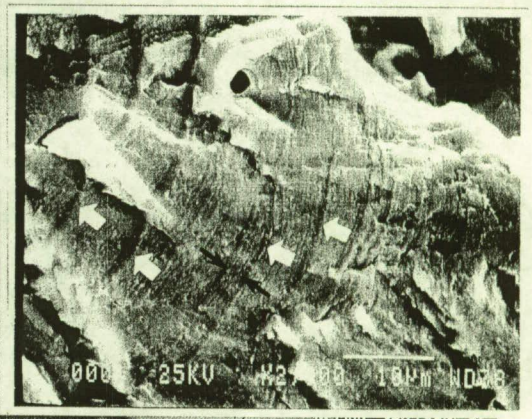
Materials Analysis

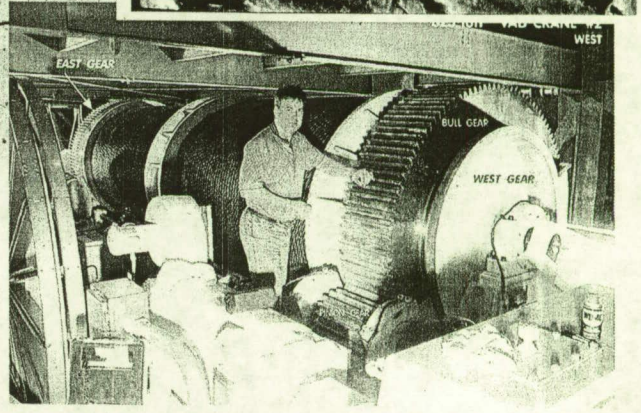
- Materials/Mechanical Failure Analysis
- Fractography (SEM) / Microscopy
- High energy real-time radiography
- Pneumatics / Hydraulics
- Metrology
- Dissection and disassembly
- Nonmetallic materials analysis
- Metallurgy

Failure analysis of an SRB fuel (N2H4) service cart showed that cart could not be reused, preventing possible unsafe operation









Testbeds for Component/Subsystem Technologies

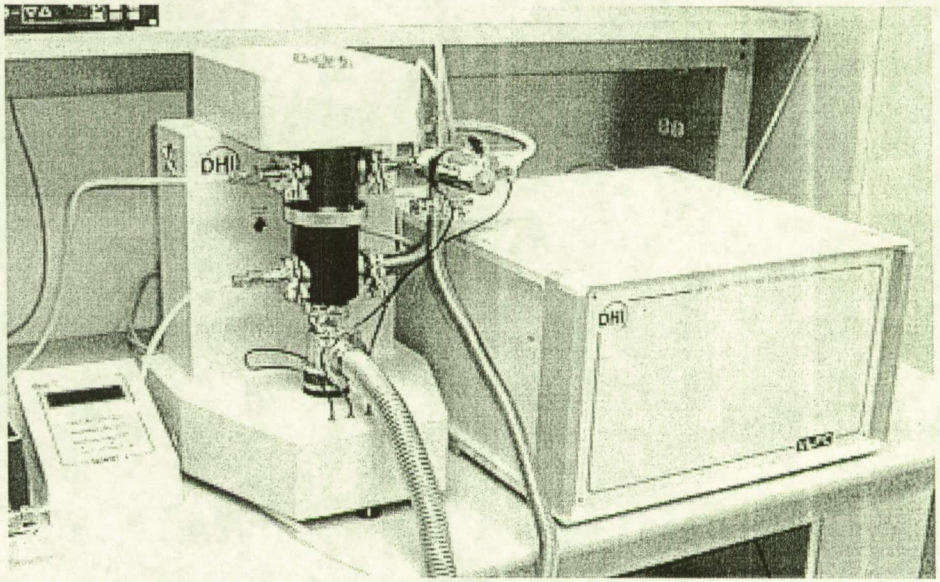
(Electrical / Electronics Failure Analysis Laboratory)

Calibration, Metrology and Standards

- Program Manager and subject matter expert for agency metrology and calibration program
- Center rep for agency metrology & cal working group (surveillance of KSC standards & calibration effort)

Recently developed an automated primary standard for very low gauge and absolute pressures (afforded the agency a calibration capability in pressure ranges never before achievable (1-2 kPa)

Currently working on a very low flow standard

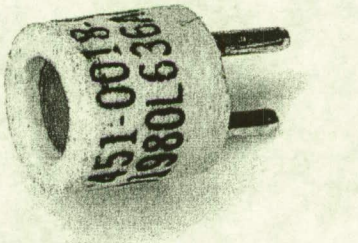


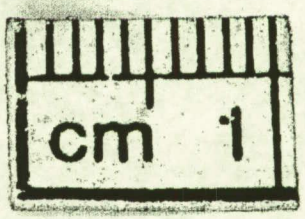
Testbeds for Component/Subsystem Technologies

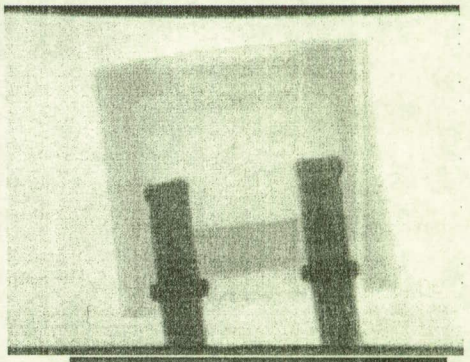
(Electrical / Electronics Failure Analysis Laboratory)

Testing/Failure Analysis

- Video/Digital photo documentation
- Micro-focus radiography (X-ray) analysis
- AC/DC power generation, testing & analysis
- Integrated Circuit dissection and probing





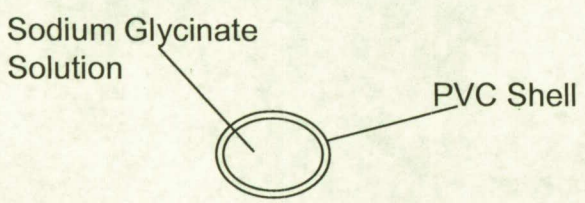


OMS HAT FUSE

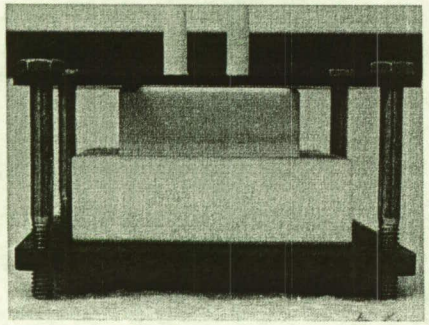
11th hour hat fuse analysis allowed on-time rollout of STS-100 (avoided $90K cost plus 3-day schedule hit)

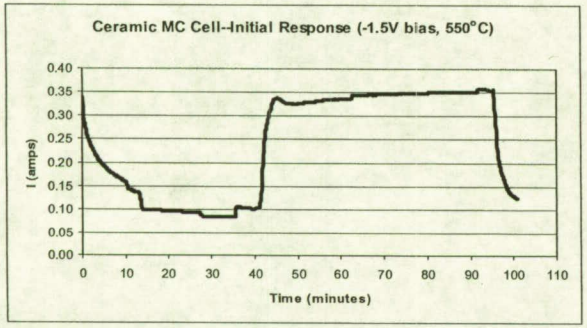
Testbeds for Component/Subsystem Technologies

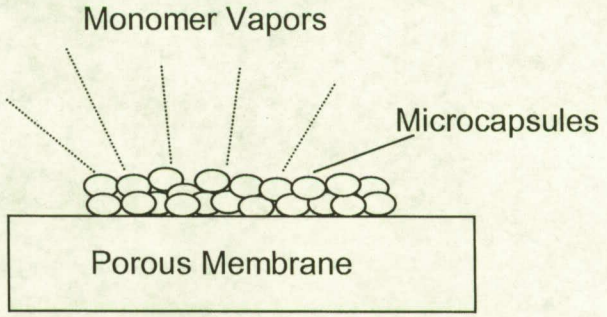
(ISRU Excavation, Separation, & Processing Laboratory)

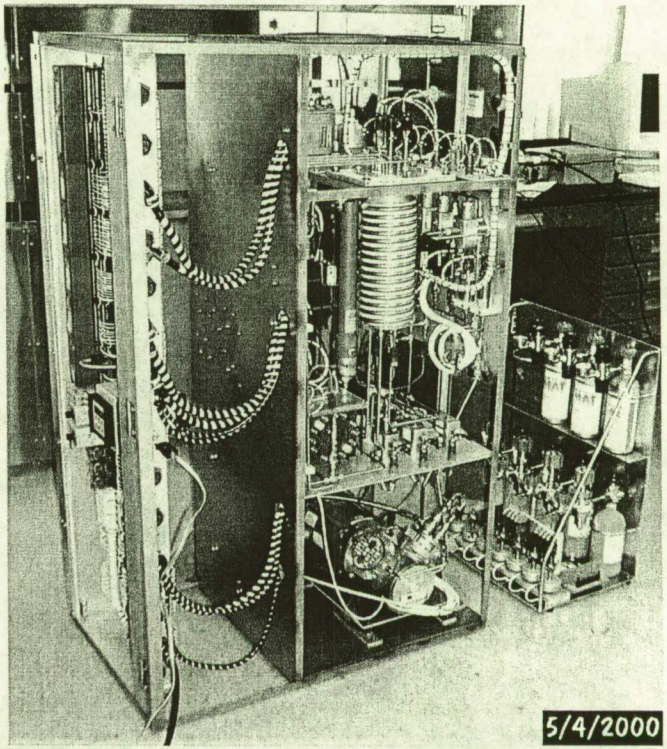


Microcapsule









Testbeds for Component/Subsystem Technologies

(ISRU Excavation, Separation, & Processing Laboratory)

HEALTH MANAGEMENT TESTBED WORKSHOP

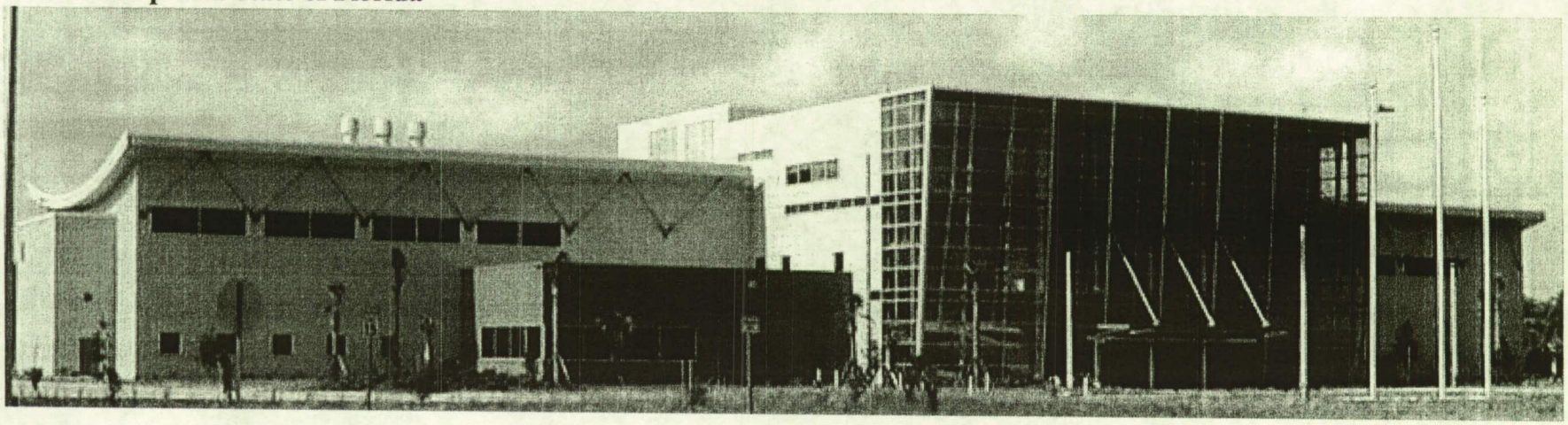
- **Rationale**
  - ISRU is a surface infrastructure activity. KSC is noted for ground infrastructure to sustain its programs. KSC procures the services of propellant producers (earth-based process). Potential for future on-site plant.
  - Relationship established with JSC – Good example of One-NASA
  - Processing – Key Technology Provider
  - Excavation and Separation – Lead for System and Technology Development
    - Probably will require partnership with external organization such as Army Cold Regions Research organization or NORCAT
  - **Expertise**
    - Several PhD Chemists on staff
    - Cold-proofing mechanisms
    - Lifting fixture and effector expertise
    - Heavy equipment expertise
  - **Capabilities**
    - Applied Chemistry Lab
    - Subsystem scale environmental chamber – needs investment to complete
  - **Exploration Related Technology Development**
    - O2 generation
      - Reverse Water Gas Shift
      - Ionic Liquids
      - Molten Carbonate
    - Gas separation
      - Hollow fiber membranes
      - Highly selective immobilized liquid membranes
    - Autonomous Control of In-Situ Propellant Production

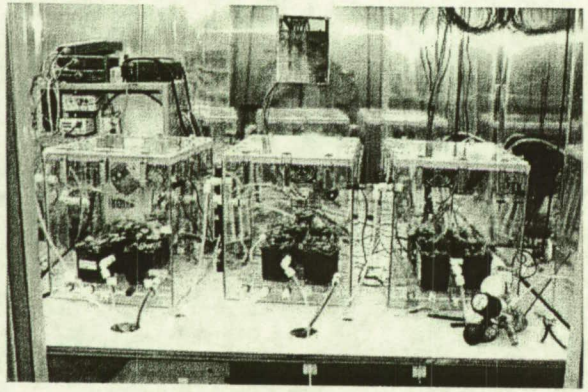
Testbeds for Component/Subsystem Technologies

(Space Life Sciences Laboratory)

HEALTH MANAGEMENT TESTBED WORKSHOP

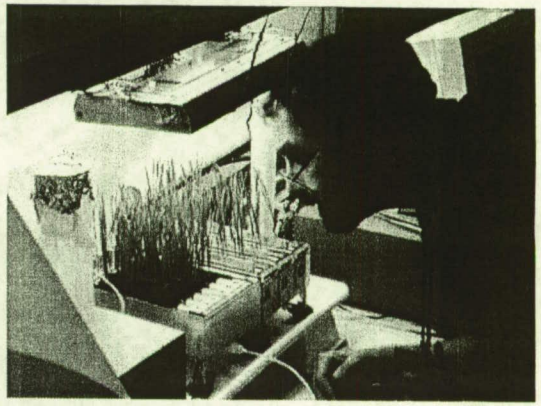
Partnership with State of Florida





Studies related to long-term effects of volatile organic compounds

Water Offset Nutrient Delivery (WONDER) Experiment



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Testbeds for System/Vehicle Engineering & Risk Reduction
(ATDC - Capabilities)

Capabilities at the ATDC include:

- Liquid Oxygen Systems
- Liquid Hydrogen Systems
- Umbilicals, Checkout and Control, and Instrumentation Systems using a "Test Demonstrator" Rocket Structure
- High Pressure Gaseous Nitrogen and Helium Systems
- Liquid Oxygen System (LOX)
  - 2–28K gal. Dewars
  - 6 re-configurable mechanical skids (piping, valves, controllers, etc)
  - Flow capacity up to 1500 GPM
- Multiple pieces of X-33 hardware
- 10,000 feet of landing runway at Cape Canaveral Air Force Station
- Command, Control, and Data Acquisition System
  - COTS hardened Allen Bradley PLC and I/O modules
  - High speed Supervisory Control and Data Acquisition (SCADA) System
  - Dual control and monitoring stations
- Utilities
  - GN2 (400,000 cubic ft. / 3000PSI)
  - Potable water
  - Power
  - Operational intercom and television systems, including closed circuit TV
  - Streaming video and web-cast
- Horizontal Processing Facility
- Inherent safety and reliability in all systems
- Green space available expansion (27 acres)

Testbeds for System/Vehicle Engineering & Risk Reduction
(ATDC – Targeted toward Testing Advanced Technologies)

The ATDC has specifically been targeted for testing advanced technologies such as:

- Integrated System Health Management (ISHM) techniques (sensors, life cycle health trending, real-time decision making, Informed Maintenance)
- Propellant Processing and Handling
- Fully integrated operations demonstrations to validate an Advanced Checkout, Control and Monitoring Systems
- Autonomous Control Architectures
- Automated and smart umbilicals tailored to vehicle designs
- Non-Toxic Orbital Maneuvering System development and testing
- Demonstration of large-scale generation, handling, storage and processing of densified LH2 and LO2
- Developed capability for rapid reconfiguration/turnaround of launch site
- Large scale launch assist technology development
- Advanced Range technology development
- Cryogenic Tank Cycling
- Thermal Vacuum TestingTPS Thermal Cycling and Integration
- Power and Actuation
- Automated Inspection, Command, and Control
- Vibration and Acoustic Testing
- Flight Operations Demonstrator

Testbeds for System/Vehicle Engineering & Risk Reduction
(ATDC - ATDC Relevance to ISHM)

- The Advanced Technology Development Center is a national proving ground located at Space Launch Complex (SLC) 20 at Cape Canaveral Air Station (CCAS). The facility is designed for testing advanced range and spaceport technologies in an operational environment. It provides a large scale testbed for integrated technology research, demonstration, qualification and testing activities in a high fidelity environment. ATDC provides the capability to perform component and subsystem testing as well as operations processing tests at the system level.

- The ATDC testbed allows Integrated Systems Health Management (ISHM) and other technologies to be implemented and validated in an environment that mimics the operational environment while remaining shielded from the schedule impacts associated with an operational program (Shuttle, ELV, ISS, etc.). The testbed allows for full-scale demonstration, testing and qualification of technologies within an infrastructure that accurately resembles a launch environment. Technology projects under development, which show promise in the laboratory, can be deployed and qualified at the ATDC under "real world" conditions. The ATDC is specifically designed to move technologies from the Technology Readiness Levels of TRL-4 to TRL-6.

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Summary
(Specific Lab and Testbed KSC Points of Contact)

HEALTH MANAGEMENT TESTBED WORKSHOP

Primary Contact for KSC Testbeds:

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Melanie.R.Chan@nasa.gov

Individual Contacts for KSC Labs and Testbeds:

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Cryogenics Testbed
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Phone: (321) 867-7557
Email: James.E.Fesmire@nasa.gov

Launch Systems Testbed
Contact: Bruce Vu
Phone: (321) 867-2376
Email: Bruce.T.Vu@nasa.gov

Corrosion Testbed
Contact: Luz Calle
Phone: (321) 867-3278
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Electrostatics & Surface Physics Testbed
Contact: Carlos Calle
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Applied Chemistry Laboratory
Contact: Clyde Parrish
Phone: (321) 867-8763
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Applied Physics Laboratory
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